Gluon polarization and higher twist effects

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CONTENTS

1) Status of higher twist (HT) terms

2) Recent developments concerning $\Delta G(x)$

3) Comparison of LSS06 and COMPASS PDFs

4) Can we distinguish positive from negative $\Delta G(x)$?

HT in the ratio $\frac{g_1}{F_1}$

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Then

$$\frac{g_1}{F_1} \approx \frac{g_1^{LT}}{F_1^{LT}}\Big[1 + \frac{g_1^{HT}}{g_1^{LT}} - \frac{F_1^{HT}}{F_1^{LT}}\Big]$$

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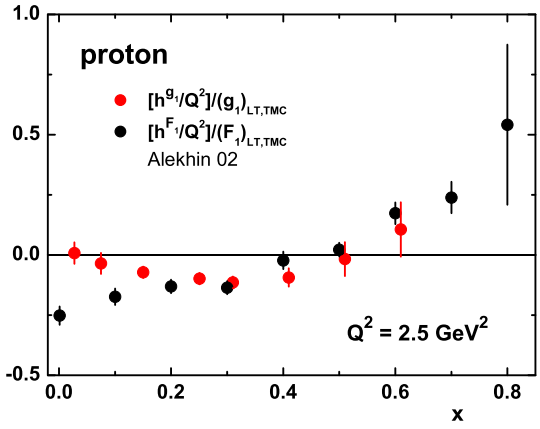
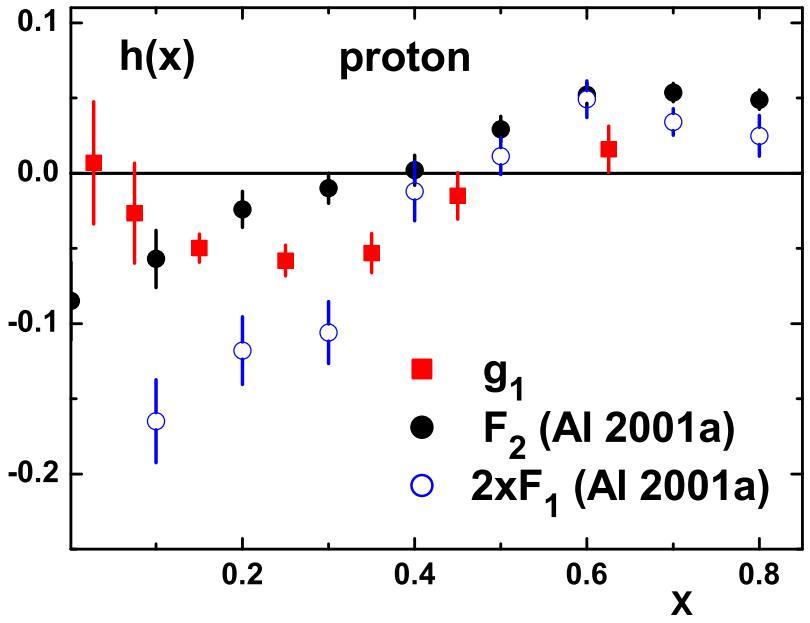
So we need a cancellation between $\frac{g_1^{HT}}{g_1^{LT}}$ and $\frac{F_1^{HT}}{F_1^{LT}}$

Figure: Alekhin

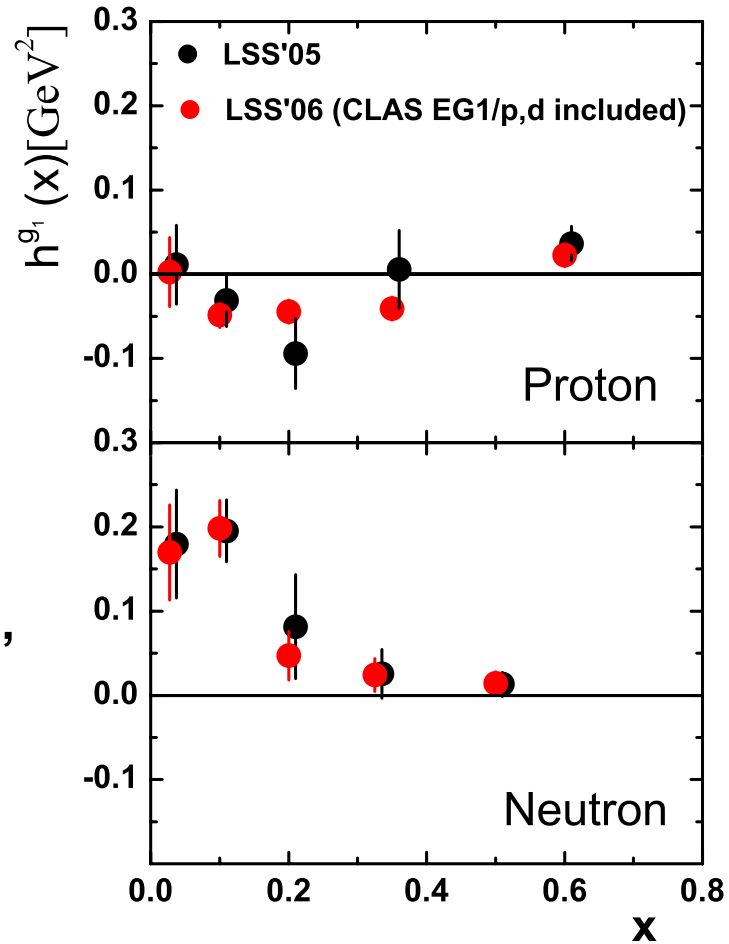

proton
$[h^{g_1}/Q^2]/(g_1)_{LT,TMC}$
$[h^{F_1}/Q^2]/(F_1)_{LT,TMC}$
Alekhin 02
Q^2 = 2.5 GeV^2
1.0
0.5
0.0
-0.5
0.0
0.2
0.4
0.6
0.8
x


h(x)
proton
0.1
0.0
-0.1
-0.2
0.2
0.4
0.6
0.8
x
g1
F2 (Al 2001a)
2xF1 (Al 2001a)

Effect of CLAS'06 p and d data *(PL B641, 11, 2006)* on polarized PD and HT

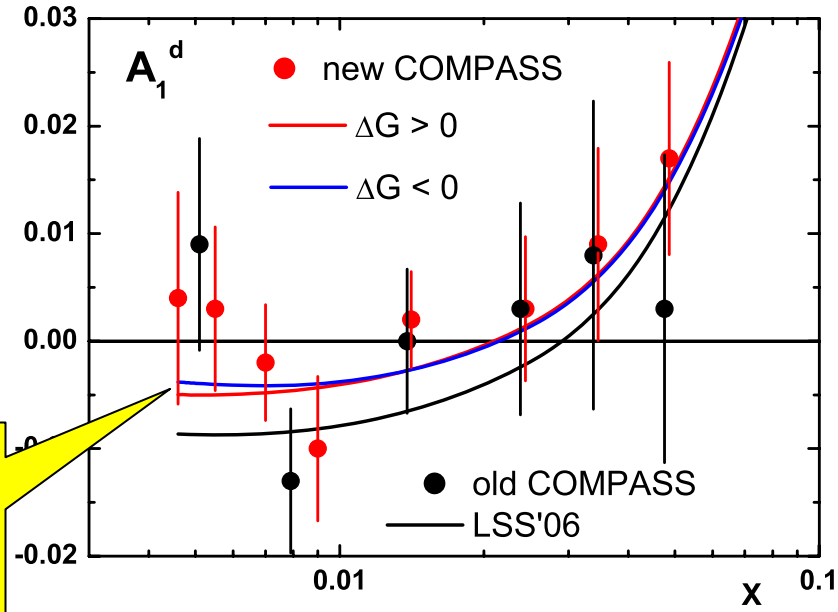
- Very accurate data on g_1^p and g_1^d at low Q^2: 1~ 4 GeV^2 for x ~ 0.1 - 0.6
- The determination of HT/p and HT/n is significantly improved in the *CLAS* x region compared to HT(LSS'05)
- As expected, the central values of PPD are practically not affected by *CLAS* data, but the accuracy of its determination is essentially improved (a consequence of much better determination of HT corrections to g_1)

LSS'05: PR D73 (2006)



Effect of COMPASS'06 A_1^d data (*hep-ex/0609038*) on polarized PD and HT

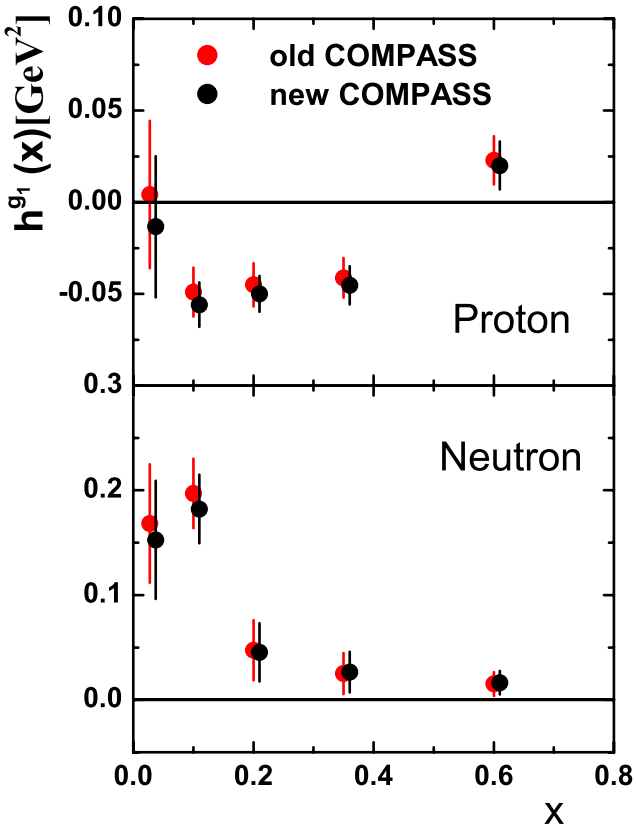
In contrast to the *CLAS* data, the *COMPASS* data are mainly at large Q^2 and the only precise data at small x: $0.004 < x < 0.02$. The new data are based on 2.5 times larger statistics than those of *COMPASS'05*

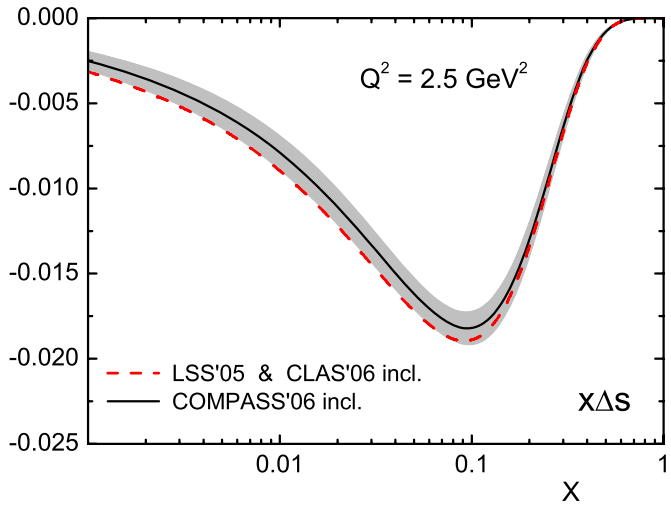


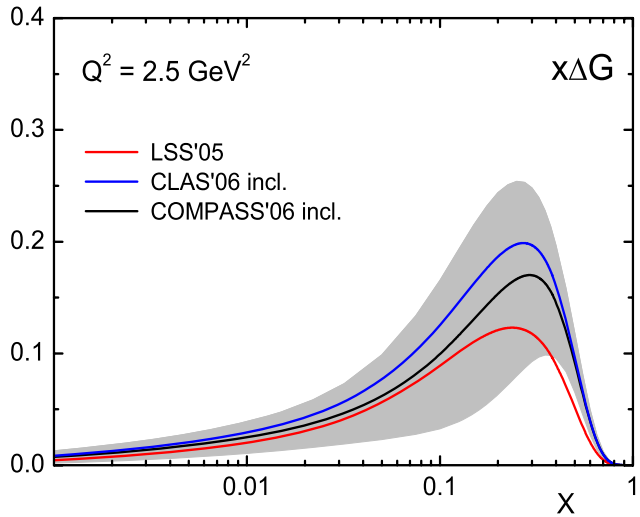
The new QCD curves corresponding to the best fits lie above the old one at $x < 0.1$

- $(\Delta u + \Delta \bar{u}),\ (\Delta d + \Delta \bar{d})$ **do NOT change**
- **$x|\Delta s(x)|$ and $x\Delta G(x)$ and their first moments Δs and ΔG slightly decrease**

5 x-bins for HT







The values of HT are practically NOT affected by *COMPASS* data excepting the small x where Q^2 are also small

ATTEMPTS TO MEASURE ΔG

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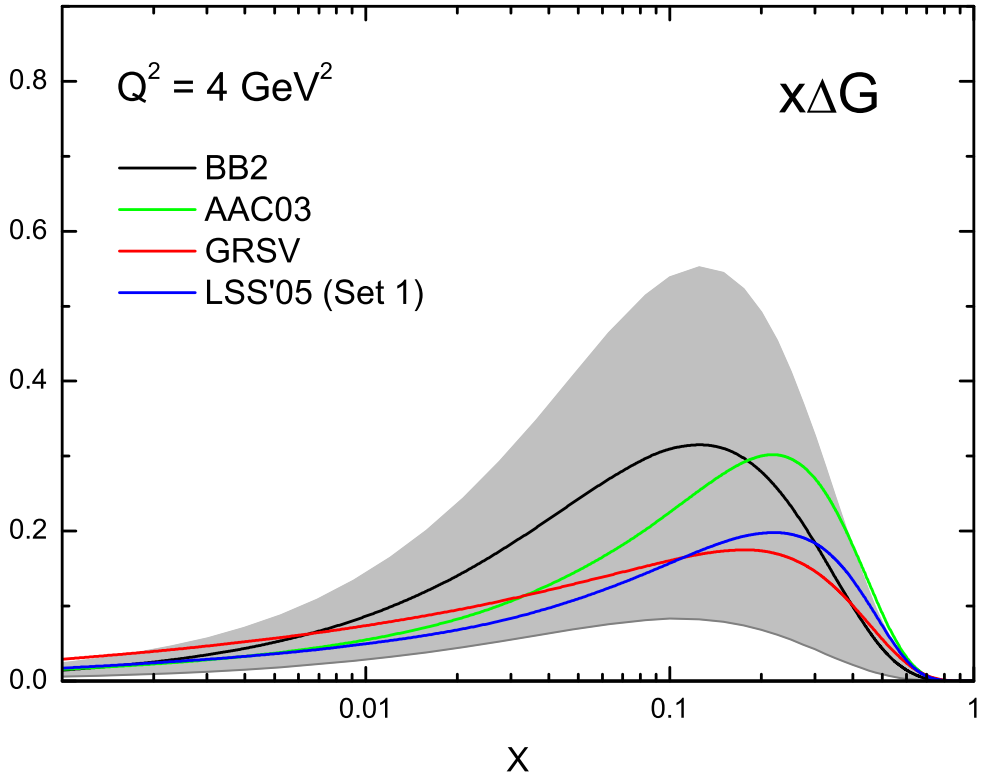
LSS used a very simple parametrization

$$x\Delta G(x) = \eta_g A_g x^{a_g}[xG(x)]$$

The figure compares various results for $\Delta G(x)$ as of a couple of years ago.



This is a test.

For reasons that I do not understand, with the inclusion of recent data, we get equally good fits with positive, negative and sign-changing $\Delta G(x)$, provided we include higher twist terms. These are particularly demanded by the CLAS data.

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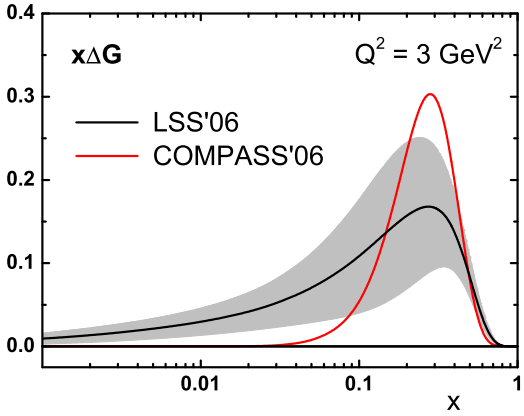
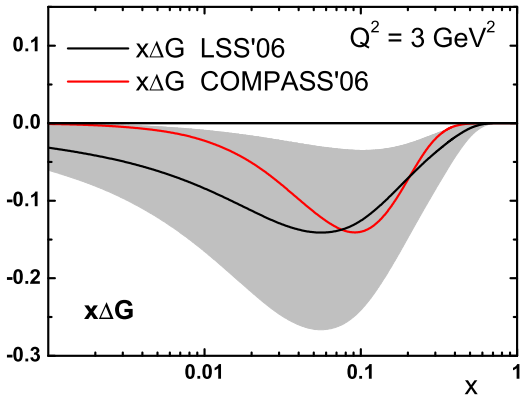
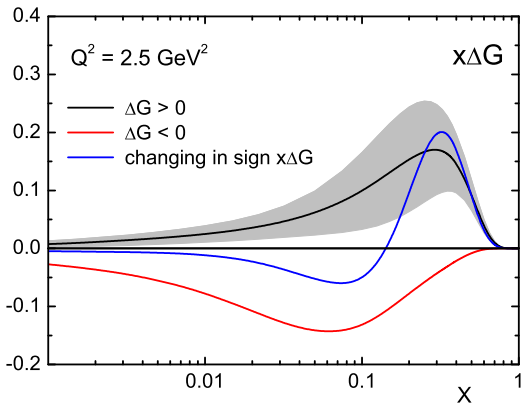
Figures show: comparison of LSS06 with COMPASS06 for positive $\Delta G(x)$, and for negative $\Delta G(x)$. Also comparison of the three LSS06 versions of $\Delta G(x)$


0.4
0.3
0.2
0.1
0.0
xΔG
Q² = 3 GeV²
LSS'06
COMPASS'06
0.01
0.1
1
x


0.1
0.0
-0.1
-0.2
-0.3
xΔG LSS'06
xΔG COMPASS'06
Q² = 3 GeV²
xΔG
0.01
0.1
1
x


0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
Q² = 2.5 GeV²
xΔG
ΔG > 0
ΔG < 0
changing in sign xΔG
0.01
0.1
1
X

Another approach to ΔG is via $c\bar{c}$ production in DIS. Requires high energy lepton beam: COMPASS!

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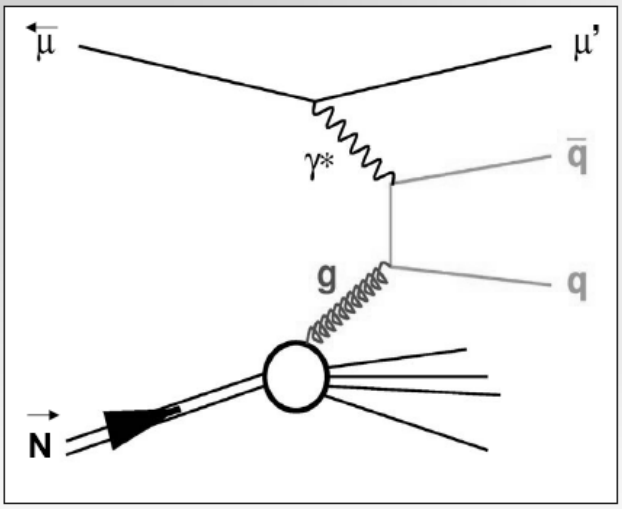
No intrinsic charm in nucleon. Therefore $\gamma - gluon$ fusion. Feynman diagram:

Photon-Gluon fusion



q = c
"OPEN CHARM"
cross section difference
in charmed meson production
→ *theory well understood*
→ *experiment challenging*

q = u,d,s
"HIGH p_T HADRON PAIRS"
cross section difference in 2+1
jet production in COMPASS:
events with 2 hadrons with
high p_T
→ *experiment "easy"*
→ *theory more difficult*

COMPASS

Figure shows some of the COMPASS and other results for $\Delta G(x)/G(x)$ compared with the 3 LSS06 polarized gluon densities divided by MRST'02 unpolarized gluon density

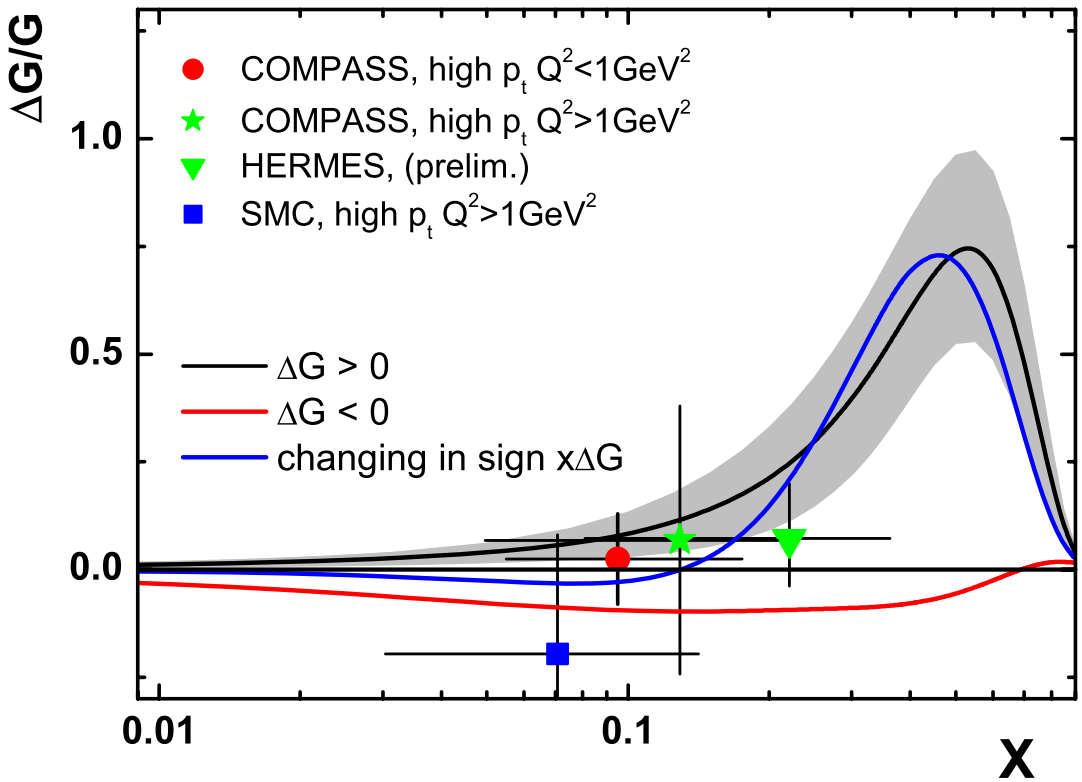
Comparison with directly measured ΔG/G at $Q^2 = 3\ GeV^2$

MRST'02 unpolarized gluon density is used for G(x)

The error band corresponds to statistic and systematic errors of ΔG

The error bars of the experimental points represent the total errors

The most precise value of ΔG/G, the *COMPASS* one, is well consistent with any of the polarized gluon densities determined in our analysis



Clearly the data are perfectly compatible with all the polarized gluon densities and there is no hint of a larger polarized gluon density than found in DIS.

Comparison of LSS06 and COMPASS PDFs

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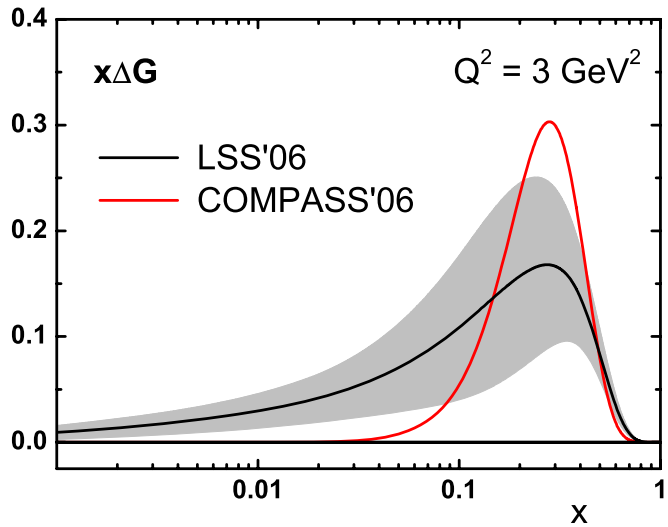
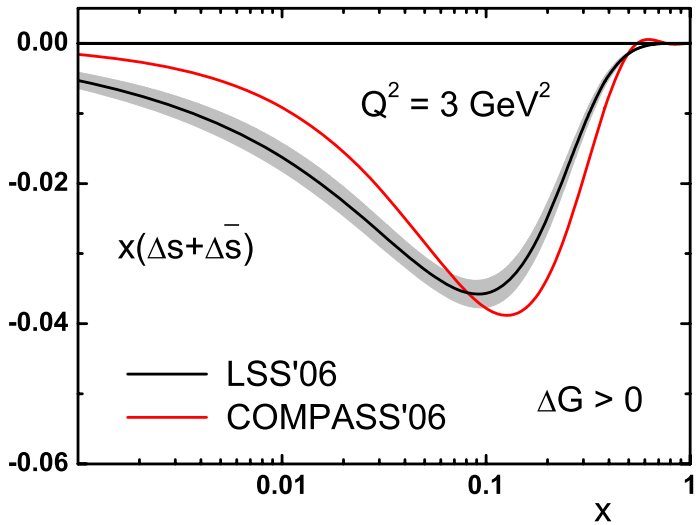
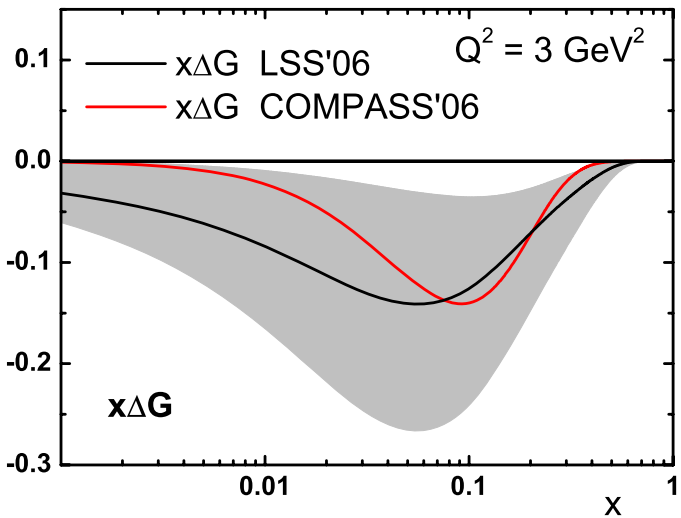
Some difference in $\Delta s + \Delta \bar{s}$ and consequently in $\Delta\Sigma$: Figures

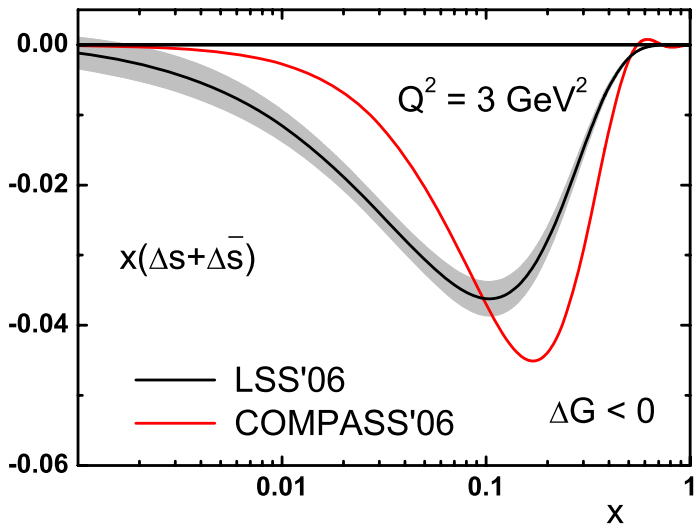
- **$x\Delta s$ are different, especially in the case of $\Delta G < 0$**

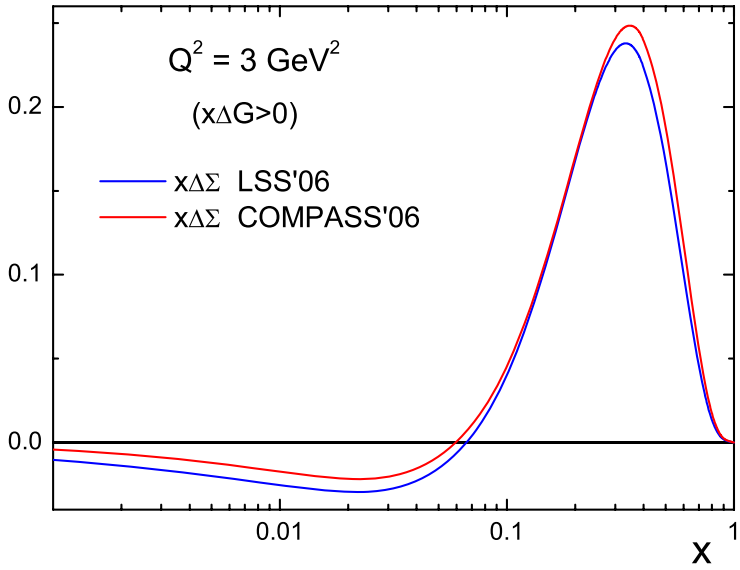
- **$x\Delta G$ positive obtaned by COMPASS is more peaked than our**

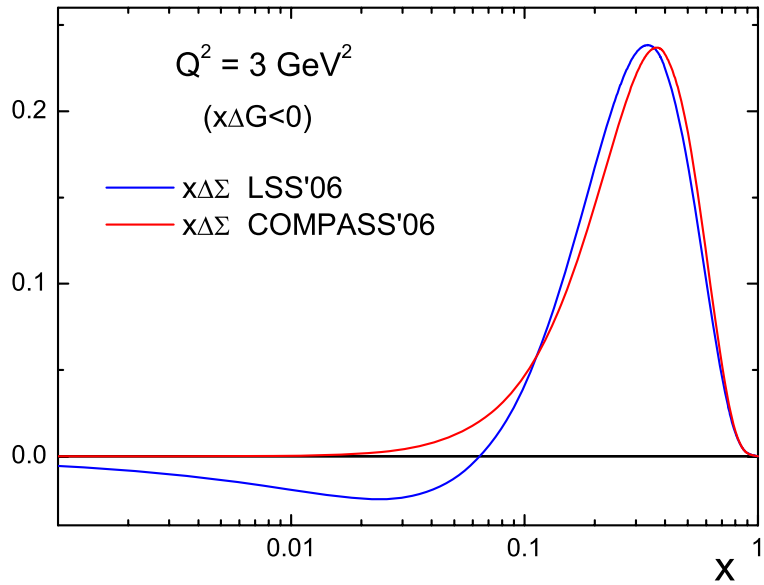


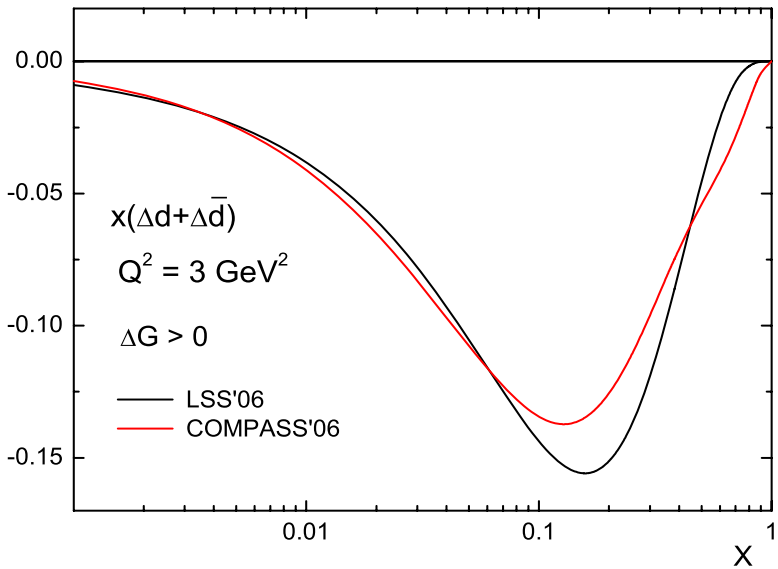


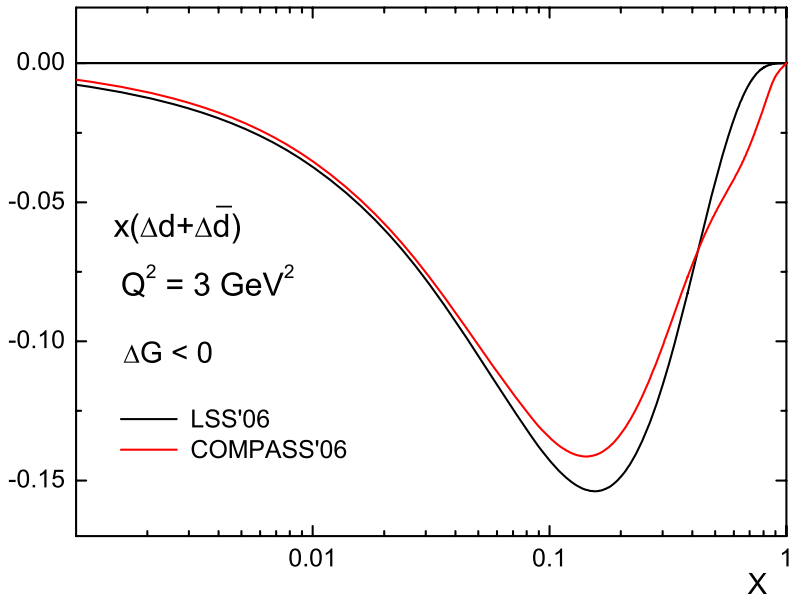





Q^2 = 3 GeV^2
(xΔG>0)
xΔΣ LSS'06
xΔΣ COMPASS'06
0.2
0.1
0.0
0.01
0.1
1
x


Q^2 = 3 GeV^2
(xΔG<0)
xΔΣ LSS'06
xΔΣ COMPASS'06
0.2
0.1
0.0
0.01
0.1
1
x


x(Δd+Δd̄)
Q^2 = 3 GeV^2
ΔG > 0
LSS'06
COMPASS'06
0.00
-0.05
-0.10
-0.15
0.01
0.1
1
x


x(Δd+Δd̄)
Q^2 = 3 GeV^2
ΔG < 0
LSS'06
COMPASS'06
0.00
-0.05
-0.10
-0.15
0.01
0.1
1
x

The main differences are in the NEGATIVE ΔG case:

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Δs and $\Delta\Sigma$ are different. The sign change in

$\Delta\Sigma$ was not permitted by the COMPASS parametrization

For a detailed discussion of how the CLAS and COMPASS results affect the UNCERTAINTIES in the PDFs, see SIDOROV's talk at the XII Workshop on High Energy Spin Physics (DSPIN-07), Dubna, September 2007

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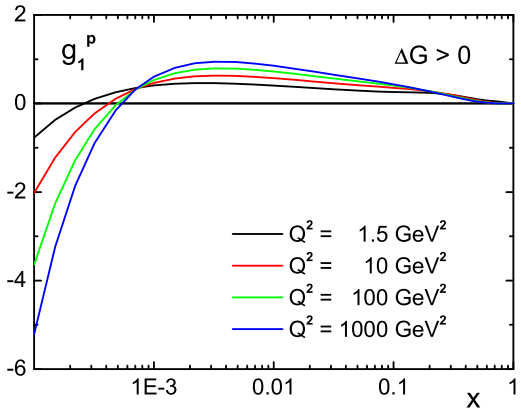
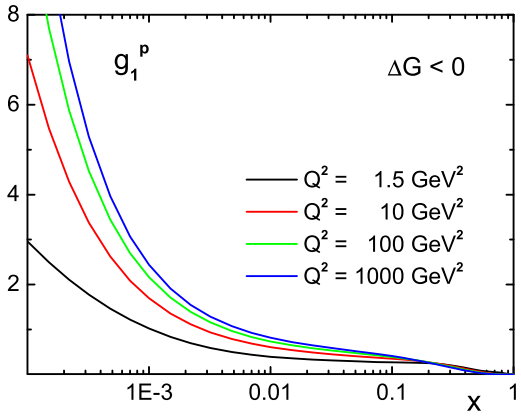
Figures show $g_1(x)$ at very small x for $1 < Q^2 < 1,000 GeV^2$ for the two signs of $\Delta G(x)$, using the LSS06 PDFs


2
0
-2
-4
-6
g_1^p
ΔG > 0
Q^2 = 1.5 GeV^2
Q^2 = 10 GeV^2
Q^2 = 100 GeV^2
Q^2 = 1000 GeV^2
1E-3
0.01
0.1
1
x


8
6
4
2
g_1^p
ΔG < 0
Q^2 = 1.5 GeV^2
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Q^2 = 100 GeV^2
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1E-3
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6) $g_1(x)$ at very small x and large Q^2 (EIC!!!) could settle the ΔG question